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gaseous emissions from municipal incinerators

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U.S. ENVIRONMENTAL PROTECTION AGENCY
1974

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FOREWORD

Incineration is still a widely used method for processing solid wastes in large metropolitan areas, although increasingly stringent air pollution laws may require that many existing incinerators be modified or closed. Incineration reduces the volume of wastes requiring disposal, but in so doing, it produces gases and liquids that are dispersed into the environment. At the time this report was written, few studies had been made of the emissions from municipal incinerators. And of those that had been made most were limited in scope, being confined generally to selected emissions. This experimental study, conducted under two contracts with New York University, is broader in scope than earlier studies, covering gaseous emissions, quenchwater, and ash from four municipal incinerators in the New York City metropolitan area.

Although the data were gathered in 1968 and some of the incinerators surveyed are no longer in operation, we believe that the data are useful to add to the body of available information on this important aspect of the environmental impacts of incineration.

--ARSEN J. DARNAY
Deputy Assistant Administrator
for Solid Waste Management

PREFACE

One of the significant byproducts of the intricate chemical reactions that sustain life in all forms is waste. Those mechanisms, both natural and synthetic, which have propagated and multiplied the homo sapiens form are prime examples. Human population has not only rapidly increased, but has concentrated in chosen geographical locations. Massed in a synthetic environment designed for modern existence, man continues to live, multiply, and produce enormous quantities of agricultural, mineral, industrial, and urban wastes.

In larger cities, the solid waste is being constantly removed from the environment and "destroyed" in a number of ways. A common practice is incineration. Thus, large incineration plants have been designed and constructed for the purpose of municipal refuse disposal.

But, alas, matter can neither be created nor destroyed, only changed in form. Thus, solid waste is presently converted (via incineration) in part to gases and liquids. The gases are dispersed into the life-essential air, and the liquids pour into our rivers, bays, and oceans. Clearly, this system is far from satisfactory. True, the solid volume of the waste is reduced significantly, but little has been done to reduce obnoxious gas and liquid emissions from incinerators.

The products of the combustion of solid waste are many and varied. They include numerous classes of organic as well as inorganic compounds, certainly not all identified. The composition of the effluent changes

radically with the nature of the refuse charge, which is itself constantly changing.

The relationship among these changing parameters has not been satisfactorily established. The rate of discharge of many of the known emissions has not been adequately recorded. The synergistic and accumulative effects of these emissions on man remain a mystery. An understanding of their nature, quantity, and effects, and, subsequently, of their control is prerequisite to the total elimination of substances that can upset and eventually destroy the ecological cycles that are so necessary to life.

Elimination of waste is today as necessary to the efficient function of a life colony as is its food, water, and air supply. The study of ways and means of solid waste management is, therefore, essential. Since incineration is perhaps the most widely used method for the processing of solid waste in large metropolitan areas before final disposal, the overall efficiency of incinerator units used for this purpose must be evaluated in efforts to optimize their operation.

The authors are pleased to acknowledge the expert advice received throughout from Professor Elmer R. Kaiser, Chemical Engineering Department, New York University, who participated in this study as consultant. We are also indebted to Maurice M. Feldman, Acting Commissioner, and A. Cuciti, Principal Engineer, of the Department of Sanitation of New York City, for permission to conduct our studies at various municipal incinerator plants and for making available to us valuable operational information. Their spontaneous and courteous cooperation as well as

the cooperation of a number of the various plants' personnel is gratefully appreciated. Especially, we recognize and appreciate the significant contribution to the experimental program made by the following members of the Chemical Engineering Department of New York University: Mrs. Gonul Kocamustafaogullari, Analytical Chemist-Assistant Research Scientist; John Hornyak, Laboratory Technician; Salah Rahal, Research Assistant; and Charles Lance, Research Aide. Our thanks also to Professor Lee Wikstrom, who assisted in the literature research conducted during the first six months of the project.

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GASEOUS EMISSIONS FROM MUNICIPAL INCINERATORS

A Literature Search and Experimental Study

Studies of emissions from municipal incinerators have been limited in number as well as in scope. This report first presents a review of what is generally known about gaseous emissions, and the literature review is followed by the results of an experimental study of gaseous emissions, quench water, and residual ash from four municipal incinerators in the New York City metropolitan area. The literature search was conducted as a preliminary study in the spring and summer of 1967 prior to the experimental investigation. This literature search is summarized below and is not being published in any more detail. The experimental study is also summarized, but is followed by a detailed account of the investigation.

Summary of Literature Search

The results of outstanding investigations are presented, discussed, and evaluated in publications by Rehm, Kanter, et al., Tuttle and Feldstein, Stenburg, Kaiser, Hangebrauck, et al., Flood, Jens and Rehm, Walker, and Hutchinson.[1-11] Some of these studies were concerned only with particulate, carbon dioxide, carbon monoxide, water, oxygen, and nitrogen emissions under normal incinerator operating conditions. Some were, in addition, concerned with how the respective quantity of each emission was affected by such variables as underfire and overfire air agitation of fuel bed, amount of refuse loaded, batch versus continuous incineration, and the size and type of incinerator and cleaning equipment. A limited number of papers reviewed were concerned with emissions from municipal incinerators and included data on

emissions other than particulate, carbon dioxide, carbon monoxide, water, oxygen, and nitrogen. Outstanding among this group are the publications by Kanter, Stenburg, and co-workers, Walker, Hutchinson, and the Stanford Research Institute.[2,5,10-12] Included in such publications were data from the quantitation of oxides of sulfur, sometimes ammonia, and organic pollutants. The organic pollutants were usually classes of compounds having the same functional group. Each class or family was then quantitated and reported as the equivalent of a representative member of that class. Thus a typical analysis included values for carbon dioxide, carbon monoxide, oxygen, nitrogen, water, perhaps acetylene and ammonia, particulate matter, oxides of nitrogen as NO_2, oxides of sulfur as SO_2, total hydrocarbons as hexane or methane, aldehydes as HCHO, and organic acids as CH_3 COOH. These measurements were generally conducted during normal, steady-state incinerator operating conditions.

Detailed identification and quantitation of emissions have been restricted to particulates and hydrocarbons. Papers by Kanter, Kaiser, and Jens and Rehm describe results of detailed analyses of particulates from stack effluent and collector catch.[2,6,9] The data of Jens and Rehm included values for 19 metals, 5 anions, and 2 nonmetals present in the emissions. The data of Kanter and colleagues included values for 21 metals present. The results of a relatively detailed source-sampling program to determine the pollutant emissions from many types of combustion processes were reported by Hangebrauck.[7] Emission levels of polynuclear hydrocarbons, particulate matter, carbon monoxide, total

gaseous hydrocarbons, oxides of nitrogen, oxides of sulfur and formaldehyde were measured for heat-generation sources that burned coal, fuel oil, and natural gas, and for incinerators that burned municipal-type refuse. Also, the polynuclear hydrocarbon concentrations in particulate matter emitted from open fires burning household refuse, automobile tires, grass and hedge clippings, and automobile bodies were determined. Emission levels of benzo(a) pyrene and a number of other specific polynuclear hydrocarbons were given particular consideration because of the demonstrated or potential carcinogenic activity of these compounds. Using gas-chromatographic techniques, Tuttle and Feldstein analyzed the effluents from a series of incinerators (not all municipal) for C_2 to C_6 hydrocarbons. Their resulting publication contains data from the quantitation of C_3, C_4, C_5, and C_6 fractions (saturated plus unsaturated) and from the identification and quantitation of a number of specific hydrocarbons, e.g., acetylene, ethylene, ethane, n- and i-butane, 3-methylbutene-1, pentene-1, n-pentane, 2-methylbutene-2, 2-methylpentane, 3-methylpentane and n-hexane.[3]

The paper by Kaiser appeared to be the only publication reporting a study of the effluents from municipal incinerators in the New York City metropolitan area.[6] Recorded gaseous emission data do not, however, include values for oxides of nitrogen, oxides of sulfur, ammonia, or any organics, although as noted above, particulate composition was well defined.

Chemical analyses of stack effluents at startup have, in general, been limited to carbon dioxide, carbon monoxide, water, nitrogen, oxygen,

and particulates. Seasonal variations in the composition of airborne emissions from municipal incinerators have not as yet been recorded. Variations in the rate of discharge when the incinerator is being operated at design capacity and/or at capacity loading that meets local air pollution control requirements have not been determined for many of the effluent constituents. In addition, little or no emphasis has been placed on the detection of those emission components which are toxic or potentially toxic to man, for example, cyanides, fluorides, hydrogen chloride, hydrogen sulfide, chlorine, organometallics, and volatile phosphorus compounds.

Clearly then, a great deal of additional data is needed before the effect of stack effluents from municipal incinerators on air pollution can be fully evaluated.

It would appear that the airborne emissions from the domestic or flue-fed, rather than the municipal incinerator, were chosen as the subject for a more detailed analytical study. Thus, the Department of Air Pollution Control of the City of New York developed a comprehensive procedure for the sampling and chemical analysis of the effluents of apartment house incinerators. The results of this experimental program, which include actual field studies, appeared in a publication by Jacobs and Braverman in 1958.[13] The gases and vapors quantitated during the course of this study were: oxides of sulfur as SO_2, aldehydes as HCHO, organic acids as CH_3COOH, ammonia, hydrogen sulfide, benzene, esters as ethyl acetate, carbon monoxide and dioxide, oxygen, oxidizable sulfur

compounds, oxides of nitrogen as NO_2, phenols, and hydrocarbons as CH_4. The published results of a parallel study conducted by Kaiser and coworkers in 1959 included data from a qualitative mass-spectrographic analysis, which indicated that methane, ethylene, acetaldehyde, methyl and ethyl alcohol, propylene, and acetone were also present in emissions from flue-fed incinerators.[14] Other emission data from domestic incinerator studies were published by Hutchinson,[11] Stanford Research Institute,[12] Kanter, et al.,[2] Sterling and Bower,[15] Tuttle and Feldstein,[3] and Walker.[10]

The most detailed analytical study, describing the effluents from backyard incinerators, was conducted by Yocum and coworkers in 1956.[16] Gaseous and normally liquid materials from the effluent were collected in a conventional freeze-out train, then analyzed by infrared and ultraviolet spectrophotometry and wet chemistry. Recorded data included values for methanol, ethylene, acetone, methane, acetylene, alpha olefins, carbonyl sulfide, benzene, acids as acetic acids, phenols as phenol, aldehydes as formaldehyde, ammonia, oxides of nitrogen as NO_2, acetaldehyde, esters and guaiacol as well as for carbon monoxide and carbon dioxide. Some fractions could not be identified. This work emphasized the extreme complexity of incinerator gases. It also pointed out the need for more work toward identifying the chemical nature of this form of pollution as a means of assessing its importance.

The effects of highly volatile fuel on incinerator effluents were investigated by Stenburg and colleagues in 1961.[17] All studies were made in an experimental, multiple-chamber, prototype incinerator. Asphalt saturated felt roofing was the highly volatile fuel component

selected for these tests. Recorded emission data included values for carbon monoxide and dioxide, hydrocarbons, nitrogen dioxide, formaldehyds, and particulates. The effect of underfire airflow, excess air, secondary air, temperature, and small versus large-batch charges on some of these emissions was also investigated. Rose and co-workers also employed a small, experimental, multiple-chamber, prototype incinerator to study the air pollution effects of incinerator firing practices and combustion air distribution.[18] Specifically, these investigators obtained information about the effect of varying the amount and distribution of combustion air, the burning rate, the amount of fuel per charge, and the interval between stoking the burning fuel bed on the particulate, hydrocarbon, carbon monoxide, oxides of nitrogen, and odor emission.

Summary of Experimental Study

Seasonal variations in the general composition of the refuse, the general composition of the stack gaseous emissions and quench water, and the organic content of residual ash were experimentally evaluated as a part of the present study, at the East 73rd Street municipal incinerator plant in Manhattan. Seasonal emissions in lb per ton of refuse charged were generally highest in the spring and lowest in the summer. The lowest quantity of hydrogen chloride was found in samples collected in the fall (2.7 lb per ton refuse); the highest quantities were found in the winter (6.4 lb per ton refuse) and in the spring (8.6 lb per ton refuse). The refuse was richer in synthetic, polymeric (plastic) waste during these two seasons. Sulfur dioxide and sulfate as sulfuric acid values were related and ranged from 1.5 to 8 lb per ton of

refuse for sulfur dioxide and 5.3 to 17.5 lb per ton refuse for sulfate as sulfuric acid. Total organic acid values (0.11, 0.14, 0.16, and 0.41 lb per ton of refuse) remained essentially constant as did those for total aldehydes (0.1 to 0.3 lb per ton refuse) (Table 6).

The dissolved solids content of the quench water was lowest in the spring and highest in the winter. The ether-soluble organic content of the residual ash was lowest in the winter and highest in the spring. Summer and fall quench water and residual ash did not seem to differ significantly.

The general composition of the refuse, of the stack gaseous emissions, and of the quench water, and also the organic content of residual ash from four different types of municipal incinerators in the New York City metropolitan area were also experimentally evaluated. The lowest rate of discharge values for fall and winter (1.3, 1.8 lb SO_2 per ton of refuse; 2.3, 3.9 lb $SO_4^=$ as H_2SO_4 per ton refuse; 1.4, 1.4 lb Cl^- as HCl per ton refuse; 0.06, 0.06 lb organic acids per ton refuse) respectively were recorded at the Flushing incinerator plant, a batch-type unit (Table 14). Residue from this plant, however, was rich in gross, unburned, organic matter clearly indicating incomplete incineration. Thus, in evaluating and comparing the relative efficiencies of various incinerator plants, it is important to consider not only the quantities of airborne emissions per ton of refuse incinerated but also the nature of the furnace residue for obviously, low emission values can result from incomplete burning of the solid waste charge.

From the three continuous units, rates of discharge values recorded in the fall and in the winter were lowest for the Hamilton Avenue incinerator plant (1.5, 2.1 lb SO_2 per ton refuse; 0.09, 0.02 lb total hydrocarbons per ton refuse; 2.2, 5.0 lb HCl per ton refuse; 5.3, 7.5 lb $SO_4^=$ as H_2SO_4 per ton refuse) (Table 14). Of the three studied, this plant was the only one without water sprays. It was also the only one that burned a noticeable quantity of industrial refuse. Residual ash samples from the site, however, contained the largest amount of ether-soluble organic material.

Airborne emissions from the East 73rd Street incinerator were relatively richer in total sulfur dioxide and sulfate as sulfuric acid. The Oceanside incinerator gaseous stack effluent had the highest hydrocarbon content (3.9, 6.3 lb per ton refuse). Hydrogen fluoride was found in the effluent from three of four units only in the winter samples (0.002 to 0.16 lb per ton refuse) (Table 14).

In general, the components of the gaseous effluent resulting from the incineration of municipal refuse are many and are representative of numerous classes of both organic and inorganic substances. Aliphatic and aromatic hydrocarbons, organic acids, alcohols, keto alcohols, ketones, aldehydes, phenols, halogen, and other inorganic acids and inorganic acid anhydrides were found. The airborne emission, however, has been observed to be significantly richer in inorganics, such as hydrogen chloride, sulfate, and sulfur oxides, than in organics. This may be indicative of high combustion efficiency. Also found in the emission have been the very toxic cyanide and selenium. Most of the selenium and its compounds were concentrated in the fly ash.

The concentration of total hydrocarbons as methane in municipal incinerator stack effluent varied significantly over a relatively short period of days. Peak values of 350 and 410 ppm by v were recorded. Short term variations in the hydrocarbons emission concentration, and possibly in the concentration of other species, must be seriously considered in evaluating average rate of discharge data based on limited measurements.

AN EXPERIMENTAL STUDY

On Gaseous Emissions From Municipal Incinerators

Incineration of the complex fuel--municipal refuse--can be expected to give off both inorganic and organic solid, liquid, and gaseous products, many of which are discharged from a stack.

Stack emission measurements, however, have been selective and have mainly been concerned with such emissions as particulates, oxides of carbon, sulfur and nitrogen, and a few groups of organics. Thus, a broader study that should include gaseous, airborne emissions, quench water, and ash from municipal incinerators were initiated at New York University in December 1966. The first phase of the investigation consisted of a literature survey and data review on airborne emissions from municipal incinerators followed by preparation of an annotated bibliography of the literature surveyed and a special report that summarized the current state of knowledge of incinerator emissions and included recommendations for further studies. The second phase involved an experimental study and specifically included: (1) an evaluation of measured variations in the general composition of the refuse, in the

general composition of the stack emission and the quench water, and in the organic content of the furnace ash from one municipal incinerator; (2) a comparison of the charge, the composition of the stack emission and quench water, and the organic content of the residue from each of four different types of municipal incinerators; (3) a detailed quantitation of the gaseous effluent from one incinerator. These studies were carried out in the New York City metropolitan area.

METROPOLITAN NEW YORK MUNICIPAL INCINERATORS

The East 73rd Street Municipal Incinerator

The East 73rd Street incinerator, one of 11 municipal plants serving the City of New York, began operating in early 1957. This 660-ton-per-day plant has maintained an annual performance record of over 94 percent of design capacity. It was chosen for the seasonal variation study. Only two furnaces were in operation when samples were taken during the spring of 1968 and the winter of 1968-1969. All three furnaces were in use for most of the summer, but when the summer samples were taken, the incinerator was said to be burning "somewhat slowly." A value of 200 tons per day for each unit, a plant total of 600 tons per day, was assumed. During the fall, samples were taken when both two and three furnaces were in operation. Thus, with the exception of the "somewhat slow" summer period, all other samples and measurements were taken while the incinerator plant was operating normally. Temperatures recorded during sampling are tabulated with respective analytical and rate of discharge data. Pertinent, operational parameters are outlined below.

Furnace. There are three furnaces, each rated at 220 tons per 24 hours. Plant design capacity is 660 tons per day (T/D), continuous feed with two tandem bar and key stokers. Gases are cooled by air and water spray from 1,800 to 650 F.

Ratio. Air 40,000 (CFM) at 90 F; water at 150 gpm (roughly estimated that about 1/3 of water is not vaporized).

Stokers. Two tandem traveling bar and key grates. Feeding and drying grate included at 25°; combustion grate is horizontal.

Forced Draft Fans. One per furnace; manual control vanes. Capacity of 29,000 CFM at 6.5" wg.

Overfire Air Fans. There is one overfire air fan per furnace with a capacity of 3,000 CFM at 30" wg and introduced through 14 nozzles.

Wall Cooling Fans. In each furnace there is one wall cooling fan with a capacity of 3,000 CFM at 3.75" wg. The air is introduced through holes in silicon carbide blocks lining the lower side walls of the furnace.

Induced Draft Fans. There is one induced draft fan per furnace, with a capacity of 190,000 CFM at 5.3" wg and 700 F.

The refuse feeds continuously through water-cooled chutes by gravity onto traveling grate stokers in rectangular, refractory lined furnaces. Lower portion of walls are built up with air-cooled silicon carbide shapes.

The residue, which drops through a bifurcated chute to either of two ash conveyors, is water quenched and carried by drag chain flight conveyors into residue trucks. The continuous feeding permits high burning rates, 1800 F ± 200 F under steady-state conditions. Each furnace has a cooling

chamber with air ports, water sprays, and baffles through which the hot gases must pass. The gas temperature is reduced to approximately 650 F by a combination of air injection and water spray. The cooled gases enter the multicone cyclone separators, which remove the fly ash, and pass through the induced draft fan and out of the stack. Each of the three flues (one from each furnace) leads to a larger common stack. Samples were taken at a point, sufficiently removed from bends and fans, in the horizontal common flue on the roof.

Fly ash from cyclone collectors is carried by drag chain conveyors to the residue conveyor for disposal with the residue. Fly ash deposited in the cooling chamber is sluiced into the residue conveyor troughs.

The Hamilton Avenue Municipal Incinerator

The Hamilton Avenue municipal plant in Brooklyn is a continuous-feed unit with four furnaces, each with a design capacity of 250 T/D. Refuse feeds continuously through water-cooled chutes by gravity onto traveling grate stokers in rectangular, refractory-lined furnaces. The continuous feeding permits burning at 1800 F under steady-state conditions. Each furnace has a cooling chamber with air ports but no functional water sprays. The hot gases from each furnace enter a baffled settling chamber for removal of fly ash and pass through an induced draft fan before being emitted from the stack. There are two stacks with two flues leading to each. With the exception of the water sprays and furnace designs, the number and capacity of furnaces, and the stack and chimney layouts, the

Hamilton Avenue and the East 73rd Street incinerators are essentially identical. Samples and measurements were taken at a point on one chimney about 50 feet from the base. In every case, the incinerator plant was operating normally. Temperatures recorded during sampling are tabulated with respective analytical and rate of discharge data.

The Oceanside Municipal Incinerator

The Oceanside municipal incinerator plant in Hempstead, L.I., is a continuous-feed unit having two (10' x 44' x 52') 4-section furnaces each with a design capacity of 300 to 310 T/D, and a smaller 3-section furnace with arch and water sprays, which cool the hot furnace gases before they issue from the stack via an induced draft fan with a design capacity of 150 T/D. Each of the large furnaces embodies four 11-ft reciprocating grates. Heat generated from the combustion of the refuse converts water in boiler tubes to steam, which runs turbines for in-house electric power generation. Water from the nearby Reynolds Channel is used to quench and wash the residue. The gaseous effluent from each of the two large furnaces passes through 24 fly-ash arrestors (cyclones) before discharging from the stacks. The emission from the No. 3 furnace does not pass through fly-ash arrestors. Overfire air is fed at a rate of 7,000 to 11,000 CFM and underfire air at a rate of about 22,000 CFM. The furnace temperature normally ranges from 1700 to 1750 F.

Samples for detailed analysis were taken from the large No. 2 furnace after the fly-ash arrestors, downstream of the induced draft

fan. The temperature at this point was always about 600 F. The samples for the incinerator comparison study were taken from the No. 3 unit, in fall and in winter, about 10 feet downstream of the induced draft fan. Corresponding velocity measurements were made at a point above the base of the stack about 5 feet above rooftop. Temperatures recorded during measurements are tabulated with respective analytical and rate of discharge data.

All samples and measurements were taken while the incinerator plant was operating normally.

The Flushing Municipal Incinerator

This municipal plant, located in Queens, New York City, is a batch type unit with three furnaces, each with a design capacity of 100 tons per day. Each furnace embodies a rocking grate, which moves the residue forward towards the front to a dump grate. Occasional manual stoking is necessary. The combustion air is supplied via natural draft. Furnace temperatures averaged between 1400 to 1500 F at peak burning. Twelve-hundred-degree temperatures were recorded at loading (approximately every 20 minutes). The hot gases exit at the rear of the furnace into a cross flue the length of the plant. They then pass into a common stack. There was some fly ash settling along flue and stack where velocity drops. Samples and velocity measurements were taken at a point in the common stack about 15 feet from the base. Samples were taken with both two and three furnaces in operation during the fall and when all three furnaces

were in operation during the winter, but in all cases, the incinerator plant was operating in a normal manner. Temperatures recorded during sampling are tabulated with respective analytical and rate of discharge data.

The Refuse

The exact composition of the refuse charge at any of the four incinerators studied was not determined, for such a major task could not have been even partially completed within the time alloted for the attainment of the primary objectives, namely, the measurement of effluent components as commonly emitted and variations in concentrations. But since it is evident that the nature of gaseous incinerator effluents must vary, to an extent, with the composition of the fuel that is being incinerated at the time, an attempt was made to correlate these two parameters. Thus, during each test, the refuse charge was physically observed and its composition compared to municipal refuse which was systematically sampled and quantitated as indicated below. Any visually observed significant differences in composition were noted.

The composition of municipal refuse at the Oceanside Municipal Incinerator Plant was studied by Kaiser, Zeit, and McCaffery, of New York University during the summer of 1966 and again in the winter and spring of 1967.[19] Their results, published in the Proceedings of the 1968 National Incinerator Conference, were presented at the MECAR Symposium on Incineration of Solid Wastes on March 21, 1967, in New York City.

The refuse in the pit was first mixed by the crane operator. Four individual grapple loads of 3/4 to 1 ton each were then subsequently

studied on four different occasions. Each lot was hand sorted by 4 men into 11 categories. The refuse in each category was protected from moisture loss and weighed (Table 1).

A variation of moisture content in the combined refuse of from 19 to 42 percent was observed when no rain fell. Moisture content of the refuse collected after or during a rainfall period was not determined. Refuse, noncombustibles, and metals varied between 16 and 22 percent of the total refuse. Paper ranged between 33 and 53 percent of the refuse. The garbage (food waste) fraction ranged from 7.2 to 16.7 percent, two-thirds of which was moisture.

On every occasion when stack samples were taken at each incinerator, the pit contents were carefully inspected. Thus, the refuse was superficially sampled and analyzed (Table 1). Any obvious, significant variation in the composition was recorded. These observations resulting from this visual analysis only involved the surface covering layer that was in view. Nevertheless, by visual inspection, it may be said that the refuse collected at the East 73rd Street, the Flushing, and the Oceanside (during the fall and winter) plants appeared to be generally the same. The refuse at the Hamilton Avenue plant, collected primarily from an urban and industrial area, was discernibly richer in textiles at the time samples were taken. Specifically, there appeared to be relatively greater quantities of colored carpet and other textile scrap.

The refuse delivered to the Oceanside Municipal Incinerator was collected mainly from a suburban area. During the time the gaseous

TABLE 1

COMPOSITION OF REFUSE AT THE OCEANSIDE MUNICIPAL INCINERATOR PLANT
(Percent by weight)[19]

Category	Test 1 (1/1/66)	Test 2 (1/23/66)	Test 3 (2/21/67)	Test 4 (4/5/67)
Cardboard	1.59	6.75	5.78	6.81
Newspaper	8.88	11.27	21.35	12.75
Miscellaneous paper*	22.25	21.78	26.20	24.70
Plastic film	1.76	1.77	1.20	1.09
Other plastics, etc.†	0.69	1.67	2.34	7.73
Garbage	9.58	10.21	16.70	7.23
Grass, dirt, leaves	33.33	19.00	0.26	17.89
Textiles	3.00	3.33	2.24	3.97
Wood	1.22	6.58	1.46	3.47
Mineral (glass, etc.)‡	9.74	9.49	11.87	7.13
Metallic	7.96	8.15	10.60	7.23
Total	100.00	100.00	100.00	100.00

*Includes food cartons, paper towels, brown paper, mail, and magazine paper, but excludes newspapers and corrugated boxboard.

†Includes rubber, molded plastics, and leather goods.

‡Includes glass, ceramics, bricks, mortar, cement, and stones.

samples were collected for detailed analysis (spring and summer), the refuse in the pits contained a significant number of plastic bags filled with garden and yard trimmings and scraps, leaves, grass, and dirt. Pieces of small modern furniture were prominent during the spring season. Refuse to be incinerated at the East 73rd Street plant was collected primarily in Manhattan. The composition did not appear to vary appreciably throughout the year. Refuse for processing at the Flushing Municipal incinerator, collected from a primarily urban area, was the same in appearance as that at the East 73rd Street plant and this appearance did not seem to change significantly during the fall and winter seasons.

Sampling Apparatus

Representative sampling is of major importance in establishing the true composition of any complex system regardless of the accuracy of the analytical methods employed. Composition of the stack effluent from an incinerator burning municipal refuse is known to be quite complex. To conduct a comprehensive analysis of this effluent, a representative sample must be taken. This implies that at the point of sampling, all the components must be captured in the same proportion as they exist throughout the effluent so that obviously this point must be carefully chosen. Components of interest then must be efficiently and completely "trapped" either via filtration, adsorption, chemical reaction, condensation, etc. In addition, the quantity of sample taken for analysis must be large enough so that the components can be accurately quantitated employing predetermined analytical methods.

The sampling apparatus and procedures used for the seasonal variation and incinerator comparison studies were in accordance with (1) those described in "Selected Methods for the Measurement of Air Pollutants," U.S. Department of Health, Education, and Welfare, Public Health Service, Division of Air Pollution, May 1965, for sulfur dioxide, nitric oxide, and nitrogen dioxide, (2) methods devised, experimentally developed and tested at New York University for both organic and inorganic acids and acid anhydrides, and (3) the method of Goldman and Yagoda of the Division of Industrial Hygiene, National Institute of Health, Bethesda, Md., for aldehydes.[20] A compact manifold, incorporating all of the necessary impingers, fritted bubblers, stopcocks, metering devices, pumps, vacuum gauges, etc., was constructed and used for the quantitative sampling of sulfur dioxide, nitrogen dioxide, nitric oxide, total acids (organic as acetic acid and also hydrochloric, hydrofluoric, hydrocyanic, and sulfuric acids), and total aldehydes (Figure 1).

According to "Selected Methods for the Measurement of Air Pollutants," *loc. cit.*, sulfur dioxide in an air sample is absorbed in 0.03 N hydrogen peroxide reagent adjusted to about pH 5. The stable and nonvolatile sulfuric acid formed in this process can then be titrated with standard alkali. The sulfuric acid formed can also be quantitated gravimetrically via the precipitation of the highly insoluble barium sulfate (described in the following section). Although this method of collection was designed for ambient air containing from about 0.01 to 10.0 ppm of sulfur dioxide, it was found to be applicable for the intended purpose by experimentally demonstrating a greater than 98 percent recovery efficiency by using a series of Greenburg-Smith impingers each containing the peroxide reagent.

Figure 1. System used for the measurement of SO_2, NO_2, NO, total acids and total aldehydes

According to the original method, sulfur trioxide gas, if present, would also be recovered to some extent whereas sulfuric acid would not.

The sampling method for nitric oxide and nitrogen dioxide, as described in the same reference, was intended for the manual determination of these two species when present in the atmosphere in the range of a few parts per billion to about 5 ppm using fritted bubblers, and up to concentrations of 100 ppm when the gas is sampled in evacuated bottles. Reportedly, the bleaching effect of sulfur dioxide (30-fold ratio of sulfur dioxide to nitrogen dioxide) can be retarded by the addition of 1 percent acetone to the reagent before use. The method as described could not be satisfactorily applied for the measurement of nitric oxide and nitrogen dioxide. Even in the presence of acetone, extensive bleaching of the colored complex was often experienced within four to five hours, the time lapse before spectrophotometric measurement. Because of this and other difficulties, these measurements were considered unreliable and therefore not reported.

The quantitative capture of acids and acid anhydrides in a Greenburg-Smith impinger containing 1.5 N aqueous sodium hydroxide was experimentally demonstrated. About 99 percent of those species under consideration were repeatedly trapped, as the respective sodium salts, in the first of two identical impingers connected in series.

The efficiency of 1 percent aqueous sodium bisulfite, contained in a midget impinger, for the quantitative collection of aldehydes and ketones was similarly evaluated.

During sampling, each impinger and contents were cooled to 0 C to improve gas solubility and to minimize gas condensation in downstream rotameters.

The collection flow rates were as follows: (1) about 20 liters per minute for acid gases, (2) about 8 liters per minute for sulfur dioxide, and (3) about 3 liters per minute for aldehydes and ketones.

A 16-liter evacuated, stainless steel cylinder, fitted with a vacuum gauge, was used to collect samples (directly from the stack) for nitrogen, oxygen, carbon monoxide, carbon dioxide and total hydrocarbons analysis. Each sample was thus continuously collected over a period of about an hour. One to two liters of quench water and 1 to 2 lb of ashes were manually collected in appropriate glass jars.

Equipment used for the collection of representative samples for detailed analyses of stack effluent (not including particulates) was designed, constructed, and tested in the laboratory, and installed at the Oceanside Municipal incinerator plant. Thus photographs of the assembly were taken with the equipment in place at the sampling site, adjacent to stack No. 2 (Figures 2 and 3). The apparatus consists essentially of a probe, which embodies a glass wool filter to trap particulates, two large-volume and one small-volume specially designed coil traps,* a U-tube trap, a combination expansion chamber-heat exchange unit, flush-thru large-volume gas sampling tanks, mercury manometer, thermometer, a dry gas meter, and a high-volume vacuum pump (Figure 4). The probe, the traps, and the sampling tanks were constructed of stainless steel; stainless

*The basic design of these traps appeared in a paper by Yocom, J. E., Hein, G. M., and Nelson, H. W., J.A.P.C.A., 6, No. 2, 84-89 (1956). The original traps were constructed and used to collect relatively large, representative samples of organics efficiently from a high-volume gas flow of backyard incinerator effluent.

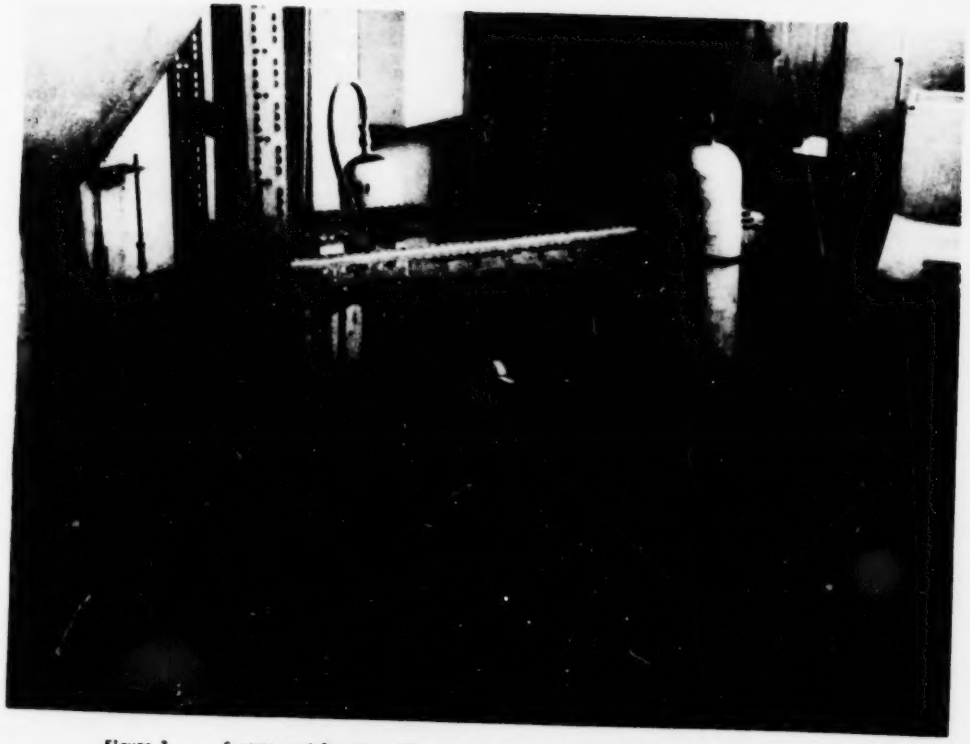

Figure 2. System used for the collection of samples for exhaustive analysis of stack effluent

Figure 3. System used for the collection of samples for exhaustive analysis of stack effluent

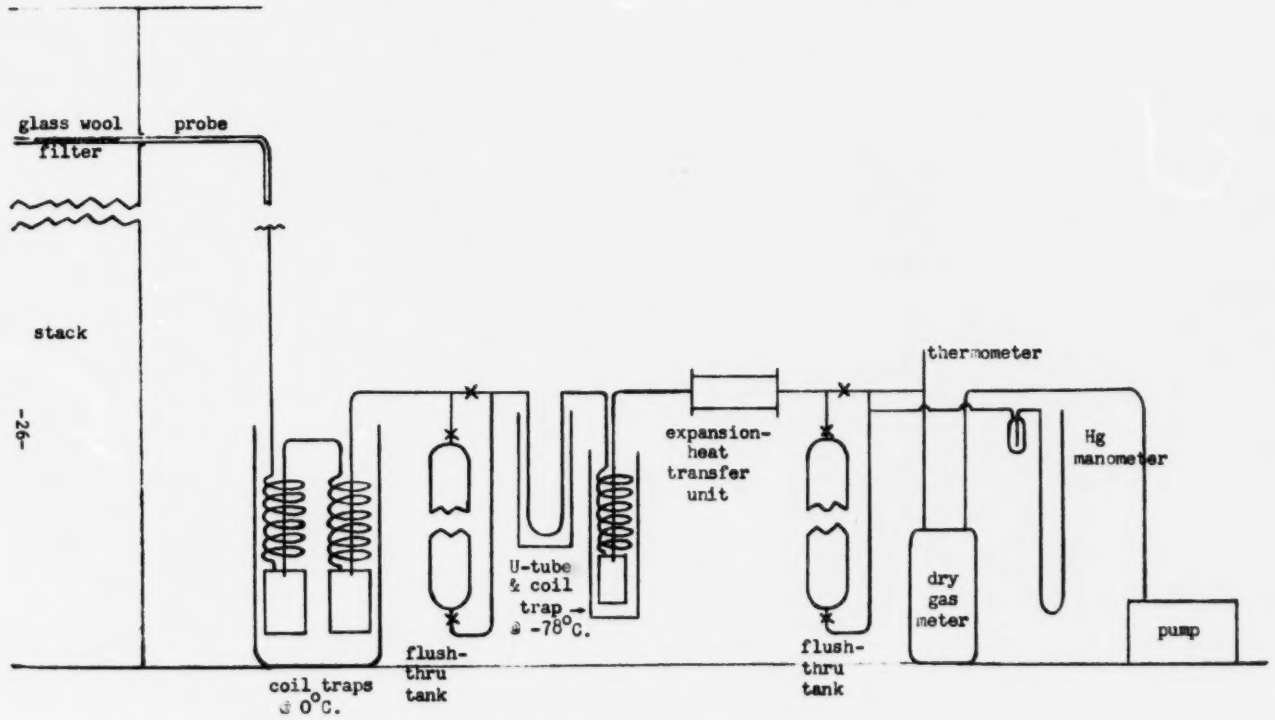

Figure 4. Schematic of apparatus used for the collection of representative samples for the exhaustive analysis of gaseous stack effluent

steel tubing and valves were wide-bore to permit high volume flow. The entire assembly permitted a gas flow of about 0.8 cubic feet per minute at a pressure of about 28 in. of mercury. During operation, the first two coil traps were maintained at 0 C, and the U-tube and small coil trap at -78 C with dry-ice acetone. Representative samples of normally gaseous components not retained in the traps were collected in the flush-thru gas sampling tanks. The high collection efficiency of this trapping system was at first experimentally demonstrated in the laboratory using ambient air spiked with known quantities of volatile organics. It was subsequently proven in practice during test runs at Oceanside.

A first version of the sampling apparatus incorporated a separate filter located outside the stack several feet from the sampling port, a water-cooled coil condenser above the first coil trap, and a spiral heat exchange unit after the third coil trap. During preliminary sampling tests at Oceanside, liquid collected in the separate glass wool filter remained surprisingly cool throughout the test run. This unit was eliminated, therefore, and the glass wool placed in a section of the probe extending into the stack. The water-cooled coil condenser was eliminated after it was found that stack gas entering this unit was already at about ambient temperature. To elininate blockage by ice crystals, which were physically swept out of the -78 C cooled coil trap by the high-volume flow of gas, the spiral heat exchange unit was replaced by a large diameter, demountable stainless steel chamber.

Velocity measurements were taken using an appropriate pitot tube following conventional velocity traverse techniques. Although these techniques were

established for power plant use, they were found adequate for the intended purpose.

Analytical Procedures

As mentioned above, the method for the quantitation of nitrogen dioxide and nitric oxide, as described in "Selected Methods for the Measurement of Air Pollutants," *loc. cit.*, could not be satisfactorily applied for the measurement of these two species. Extensive bleaching of the dye-nitrogen dioxide complex was often experienced within a few hours, even in the presence of acetone (normally added to prevent such interference by a large excess of sulfur dioxide). Because of this, nitrogen oxide measurements were considered unreliable and therefore not reported.

The sulfur dioxide, quantitatively collected and oxidized to sulfuric acid in 0.03 N hydrogen peroxide, was determined (1) volumetrically via the titration of the resulting acid with standard alkali using a color indicator or a pH meter ("Selected Methods for the Measurement of Air Pollutants," *loc. cit.*), and (2) gravimetrically via precipitation of the highly insoluble barium sulfate ("Textbook of Quantitative Inorganic Analysis," Kolthoff, I.M. and Sandell, E. B., the Macmillan Company, New York, 1947). The collected samples were in each case quantitated within 24 hours. Diluted water solutions of sulfuric acid can be stored in glass for much longer periods of time without showing any change in hydrogen or sulfate ion concentration.

Again, as mentioned above, although this method of collection and quantitation was designed for ambient air analysis, it was found to be

applicable for the intended purpose by experimentally demonstrating a greater than 98 percent recovery efficiency by using a series of Greenburg-Smith impingers each containing the peroxide reagent.

Aldehydes and ketones, collected in 1 percent aqueous sodium bisulfite, were quantitated via the method of Goldman and Yagoda.[20] Thus after excess, unreacted bisulfite is destroyed with 0.1 and 0.01 N I_2 solutions, the bisulfite-aldehyde and the bisulfite-ketone addition compounds are dissociated in mild alkaline solution. The liberated bisulfite is then quantitatively titrated with standard iodine solution of predetermined concentration using starch as an indicator. The results are reported as formaldehyde, CH_2O.

Organic acids, reported as acetic, were quantitated as follows: Acetic, propionic and butyric via gas chromatography following the neutralization, concentration, and acidification of the collection media (aqueous sodium hydroxide), and formic via infrared spectrophotometry, following neutralization of the reaction media and isolation of salts resulting from complete evaporation. Sodium nitrate was used as an internal standard.

Nitrogen, oxygen, carbon dioxide, and carbon monoxide were determined gas chromatographically using molecular sieve and silica gel columns at ambient temperature.

Methane, ethane, ethylene, propane, propylene, i-butane, n-butane, i-pentane, n-pentane, and other hydrocarbon concentrations were also quantitated gas chromatographically using a dimethylsulfolane column in conjunction with a hydrogen-flame ionization detector. Total hydrocarbon concentration is reported as methane.

Hydrogen cyanide, collected both as the gas and as the salt in sodium hydroxide, was determined gas chromatographically and spectrophotometrically by the method of Kratochvil.[21] In the latter, the cyanide ion is quantitatively converted to cyanogen chloride with chloramine-T. Cyanogen chloride reacts with pyridine to form glutacon aldehyde. The latter forms a violet-colored complex with dimedon which absorbs in the region of 580 to 585 mμ. This method is specific for cyanide and extremely sensitive. Results are reported as hydrogen cyanide.

Chloride ion concentration was quantitated (1) volumetrically via titration with standard silver nitrate using fluorescein as an indicator ("Textbook of Quantitative Inorganic Analysis," Kolthoff and Sandell, *loc. cit.*), and (2) spectrophotometrically by the method of Martens as described in an in-house report by the Air Force Rocket Propulsion Laboratory, Edwards, California. Results are reported as hydrogen chloride.

The fluoride ion concentration was quantitatively determined by the method of Willard and Winter. This method involved the volatization of the fluorine as hydrofluorosilic acid with subsequent titration of soluble fluoride and silicofluoride with standard thorium nitrate, using a zirconium-alizarin mixture as indicator.[22]

The quench water samples were quantitated for chloride using the methods described above, carbonate via precipitation of the insoluble barium salt in mildly alkaline solution ("Textbook of Quantitative Inorganic Analysis," *loc. cit.*), and for sulphate and fluoride by methods also described above. The total dissolved solids were determined by evaporation and weighing.

Residual organic matter in the ash samples was determined via ether extraction. The soluble portion was weighed after complete evaporation of the solvent.

For the comprehensive analysis of gaseous stack effluents, identification and quantitation of specific organic components was primarily via gas chromatography and infrared spectrophotometry. Wet-chemical tests as described in "The Systematic Identification of Organic Compounds," by Shriner, R. L. and Fuson, R. C., John Wiley and Sons, Inc., New York, 1935, were also employed to establish the presence of various functional groups.

Results of Seasonal Variations Study

As noted earlier, the East 73rd Street incinerator plant in Manhattan had been chosen for this study. Samples were taken during each of the four seasons, and the analytical results and rate of discharge data for each season were compiled and compared (Tables 2 through 6) as were the results of the quench water and the organic residue analyses (Table 7).

The carbon dioxide and carbon monoxide values determined in the analyses of the emissions from May 1968 to February 1969, are low (Tables 2 through 5). This is not indicative of poor combustion efficiency but rather the result of the dilution of combustion products plus excess combustion air by a continuous large volume feed of both cooling, noncombustion air (40,000 cfm) and cooling water (150 gallons per minute), of which about two-thirds vaporizes. This relatively large volume of cooling air and water that admixes with the normal effluent also reflects a high effluent to refuse weight ratio.

TABLE 2

SOME STACK EMISSIONS FROM THE EAST 73RD STREET INCINERATOR,
NEW YORK CITY (MAY 1968)
(N_2 = 77.7%, O_2 = 10.9%, CO_2 = 2.26%, CO = 0.01%)

Component	Conc. ppm/v	Rate of discharge (ft^3/day, 356F)	Rate of discharge (ft^3/day, STP*)	Rate of discharge (g. moles, day)	lb/day	lb/ton refuse
Effluent	-	851 x 10^6	511 x 10^6	643 x 10^6	41 x 10^6	98 x 10^3
SO_2	37	31,487	18,892	23,804	3352	8
Total HC as CH_4	410	348,910	209,346	263,776	9328	22.1
Total acids as HAc†	2	1,702	1,021	1,286	170	0.41
Total Aldehydes and ketones as HCHO	1	851	511	644	43	0.10
HCl‡	70	59,570	35,742	45,035	3617	8.6
HF‡	3	2,553	1,532	1,930	85	0.20
HCN‡	0	-	-	-	-	-
H_2SO_4§	53	45,103	27,062	34,098	352	17.5

*STP, 30 inches mercury and 32F or 760 mm mercury and 0C.

†Total acids include acetic, propionic, and butyric expressed as acetic acid.

‡Chloride, fluoride, cyanide, and sulfate are expressed as the respective acids.

§Some contribution by sulfur dioxide although sulfite was not detected; sulfite is air oxidized to sulfate to some extent in alkaline solution.

TABLE 3

SOME STACK EMISSIONS FROM THE EAST 73RD STREET INCINERATOR, NEW YORK CITY (AUGUST 1968)
(N_2 = 79.3%, O_2 = 17.7%, CO_2 = 3.03%, CO less than 0.01%)

Component	Conc. ppm/v	Rate of discharge (ft^3/day, 536F)	Rate of discharge (ft^3/day, STP*)	Rate of discharge (g. moles/day)	lb/day	lb/ton refuse
Effluent	-	772×10^6	381×10^6	480×10^6	30.6×10^6	51×10^3
SO_2	13	10,036	4,953	6,241	879	1.5
Total HC as CH_4	9.5	7,334	3,620	4,561	161	0.27
Total acids as HAc†	1.5	1,158	572	721	95	0.16
Total Aldehydes and ketones as HCHO	0.4	309	152	192	13	0.02
HCl¶	81	62,532	30,861	38,885	3,123	5.2
HF¶	0	-	-	-	-	-
HCN¶	0	-	-	-	-	-
H_2SO_4§	31	23,932	11,811	14,882	3,209	5.3

*STP, 30 inches mercury and 32F or 760 mm mercury and 0C.

†Total acids include acetic; propionic, and butyric expressed as acetic acids.

¶Chloride, fluoride, cyanide, and sulfate are expressed as the respective acids.

§There was some contribution by sulfur dioxide although sulfite was not detected; sulfite is air oxidized to sulfate to some extent in alkaline solution.

TABLE 4

SOME STACK EMISSIONS FROM THE EAST 73RD STREET INCINERATOR, NEW YORK CITY (OCTOBER 1968)
(N_2 = 78.7%, O_2 = 18.2%, CO_2 = 3.0%, CO = 0.05%)

Component	Conc. ppm/v	Rate of discharge (ft^3/day, °F)	Rate of discharge (ft^3/day, STP*)	Rate of discharge (g. moles/day)	lb/day	lb/ton refuse
Effluent+	-	751 x 10^6(532)	375 x 10^6	473 x 10^6	30 x 10^6	71 x 10^3
SO_2	31	23,281	11,641	14,668	2,065	5
Total Aldehydes and ketones as HCHO	4.0	3,004	1,502	1,893	125	0.30
Effluent‡	-	824 x 10^6(527)	412 x 10^6	519 x 10^6	33 x 10^6	52 x 10^3
Total HC as CH_4	16	13,184	6,592	8,306	292	0.46
Total acids as HAc§	1	824	412	519	69	0.11
HCl¶	41	33,784	16,892	21,284	1,709	3.7
HF¶	0	-	-	-	-	-
HCN¶	0	-	-	-	-	-
H_2SO_4#	41	33,784	16,892	21,284	4,589	7.3

*STP, 30 inches mercury and 32F or 760 mm mercury and OC.

+Two furnaces in operation.

‡Three furnaces in operation.

§Total acids include acetic, propionic, and butyric expressed as acetic acid.

¶Chloride, fluoride, cyanide, and sulfate are expressed as the respective acids.

#Some contribution by sulfur dioxide although sulfite was not detected; sulfite is air oxidized to sulfate to some extent in alkaline solution.

TABLE 5

SOME STACK EMISSIONS FROM THE EAST 73RD STREET INCINERATOR,
NEW YORK CITY (FEBRUARY 1969)
(N_2 = 78.2%, O_2 = 18.7%, CO_2 = 2.98%, CO = 0.05%)

Component	Conc. ppm/v	Rate of discharge (ft^3/day, 527F)	Rate of discharge (ft^3/day, STP*)	Rate of discharge (g. moles/day)	lb/day	lb/ton refuse
Effluent	-	700×10^6	350×10^6	441×10^6	28×10^6	67×10^3
SO_2	39	27,300	13,700	17,300	2,430	5.8
Total HC as CH_4	60	42,000	21,000	26,400	940	2.14
Total acids as HAc†	<1	<700	<350	<440	<58	<0.14
Total Aldehydes and ketones as HCHO	2.3	1,610	805	1,010	66	0.16
HCl‡	76	53,200	26,600	33,500	2,700	6.4
HF‡	0	-	-	-	-	-
HCN‡	0	-	-	-	-	-
H_2SO_4§	49	34,200	17,100	21,500	4,600	11.0

*STP, 30 inches mercury and 32F or 760 mm mercury and OC.

†Total acids include acetic, propionic, and butyric expressed as acetic acid.

‡Chloride, fluoride, cyanide, and sulfate are expressed as the respective acids.

§Some contribution by sulfur dioxide although sulfite was not detected; sulfite is air oxidized to sulfate to some extent in alkaline solution.

TABLE 6

SOME STACK EMISSIONS FROM THE EAST 73RD STREET INCINERATOR, NEW YORK CITY (SPRING, SUMMER, FALL, WINTER 1968-69)
(lb/ton of refuse)

Emission	Spring	Summer	Fall	Winter
SO_2	8	1.5	5*	5.8
Total HC as CH_4	22.1	0.27	0.46†	2.14
Total acids as HAc	0.41	0.16	0.11†	<0.14
Total aldehydes and ketones as HCHO	0.10	0.02	0.30*	0.16
HCl	8.6	5.2	2.7†	6.4
HF	0.20	0	0†	0
H_2SO_4	17.5	5.3	7.3†	11.0

*Two furnaces in operation.

†Three furnaces in operation.

TABLE 7

ANALYSIS OF QUENCH WATER AND ORGANIC CONTENT OF RESIDUE FROM THE EAST 73RD STREET INCINERATOR, NEW YORK CITY (SPRING, SUMMER, FALL, WINTER 1968-69)

Component	Spring	Summer	Fall	Winter
	Quench water			
pH	5	5	10-11	9
Total dissolved solids mg/ml	0.20	2.1	2.0	4.1
Cl^- (mg/ml)	0.04	0.22	0.38	0.55
$CO_3^= + PO_4^= + SiO_3^=$ as $CO_3^=$ (mg/ml)	0.45	0.10	0.10	0.14
$SO_4^=$ (mg/ml)	0.03	0.23	0.24	0.27
	Ashes			
Percent by weight ether soluble	3.0	2.7	1.9	0.4

The seasonal measurements of refuse were compared in pounds per ton (Table 6). Spring values were the highest, with the exception of total aldehydes. Hydrogen fluoride was only found in samples taken in the spring, at the East 73rd Street incinerator. Summer measurements appeared in general to be the lowest with organic acids and hydrogen chloride as exceptions. The least amount of hydrogen chloride was found in samples collected in the fall; the highest quantities were found in the winter and in the spring. This would seem to indicate that the refuse was generally richer in polymeric (plastic) wastes during the winter and spring seasons, which was the case when the composition of refuse was compared at the Oceanside municipal incinerator plant throughout one year (Table 1).

Sulfur dioxide and sulfuric acid values, as might be expected, seemed to be related (Tables 2 through 6); in other words, they were both either high, intermediate, or low at the same time. Total organic acid values remained essentially constant as did the total aldehydes.

Since the East 73rd Street municipal plant was operating normally during each period that samples were taken, it must be concluded that variations in effluent composition were due primarily to the changing nature of the refuse charge.

The quench water was richer in dissolved solids during the winter while the ether-soluble organic content of the residue was the lowest at this time (Table 7). These two related facts indicate a high combustion efficiency at least at the time samples were taken. They are, of course, also indicative of the nature of the charge. The dissolved-solids content of the quench water was lowest in the spring, while organics in the residual

ash were the highest during this season. The fact that this indicates lower combustion efficiency is contradictory to the fact that the highest rates of discharge of inorganics were recorded in the spring. Incineration temperatures would also be expected to run somewhat higher during this season because of the increased plastics content of the refuse charge. On the other hand, the presence of increased quantities of bulky furniture and of grass and garden trimmings would be expected to have an opposite effect.

Summer and fall quench water and residue did not seem to differ significantly.

Results of the Incinerator Comparison Study

The East 73rd Street in Manhattan, the Hamilton Avenue in Brooklyn, the Oceanside on Long Island and the Flushing in Queens were the four municipal incinerator plants chosen to compare possible differences in construction and design. Stack effluent from each was sampled and analyzed both during Fall 1968 and Winter 1968-69. The analytical results and rate of discharge data for each during both seasons were tabulated (Tables 4, 5 and 8 through 13); they were also compared as pounds per ton of refuse (Table 14).

A comparison was also made of the results of the quench water analyses and the organic contents of the ashes (Table 15).

In general, the lowest rate of discharge values were recorded at the Flushing Municipal Incinerator plant, a batch-type unit (Table 14). The residue at this plant, however, was relatively rich in gross organic matter, for example, hair, vegetable and fruit pieces, charred paper, etc. (Table 15). In this case, the low emission values were indicative of relatively inefficient combustion.

Thus, the relative incineration efficiencies of various different incinerator plants cannot be evaluated on the basis of the magnitude of gaseous emission values alone. A consideration of the composition of the residue is necessary.

Of the three continuous units, the lowest rate of discharge values were recorded at the Hamilton Avenue incinerator plant in the fall and, in general, in the winter as well (Table 14). This was somewhat surprising for

TABLE 8

SOME STACK EMISSIONS FROM THE HAMILTON AVE. INCINERATOR, NEW YORK CITY
(OCTOBER - NOVEMBER 1968)

Component	Conc. ppm/v	Rate of discharge (ft^3/day, 923F)	Rate of discharge (ft^3/day, STP*)	Rate of discharge (g. moles/day)	lb/day	lb/ton refuse
Effluent	-	687×10^6	245×10^6	309×10^6	20×10^6	4×10^6
SO_2	24	16.488	5880	7416	1044	2.1
Total HC as CH_4	4.2[1]	2885	1027	1294	45.6	0.09
Total Acids as HAc[+]	<1	<687	<245	<309	<40.8	<0.08
Total Aldehydes and ketones as HCHO	0.6	412	147	185	12	0.024
HCl[‡]	45	30,915	11,025	13,900	1116	2.2
HF[‡]	0	-	-	-	-	-
HCN[‡]	0	-	-	-	-	-
H_2SO_4[‡,§]	40	27,480	9800	12,360	2665	5.3

*STP, 30 inches mercury and 32F or 760 mm mercury and 0C.

[+]Total acids include acetic, propionic and butyric expressed as acetic acid.

[‡]Chloride, fluoride, cyanide, and sulfate are expressed as the respective acids.

[‡,§]Same contribution by sulfur dioxide although sulfite was not detected; sulfite is air oxidized to sulfate to same extent in alkaline solution.

[1]A total hydrocarbon concentration of 20 ppm/v was recorded two weeks later under apparently the same (incinerator) operational conditions.

TABLE 9

SOME STACK EMISSIONS FROM THE HAMILTON AVE. INCINERATOR, NEW YORK CITY
(JANUARY 1969)

Component	Conc. ppm/v	Rate of discharge (ft^3/day, 600F)	Rate of discharge (ft^3/day, STP*)	Rate of discharge (g. moles/day)	lb/day	lb/ton refuse
Effluent	-	600×10^6	276×10^6	348×10^6	22×10^6	4.4×10^4
SO_2	15	9000	4150	5200	730	1.5
Total HC as CH_4	8.0	4800	2210	2800	100	0.2
Total acids as HAc^+	<1	<600	<276	<350	<46	<0.08
Total Aldehydes and ketones as HCHO	2.0	1200	550	693	45	0.09
$HCl^\ddagger$	89	53,400	24,600	31,000	2480	5.0
$HF^\ddagger$	0.9	540	250	315	14	0.03
$HCN^\ddagger$	0	-	-	-	-	-
$H_2SO_4^{\ddagger,\S}$	50	30,000	13,800	17,400	3730	7.5

*STP, 30 inches mercury and 32F or 760 mm mercury and 0C.

+Total acids include acetic, propionic and butyric expressed as acetic acid.

‡Chloride, fluoride, cyanide, and sulfate are expressed as the respective acids.

‡,§Same contribution by sulfur dioxide although sulfite was not detected; sulfite is air oxidized to sulfate to same extent in alkaline solution.

TABLE 10

SOME STACK EMISSIONS FROM THE OCEANSIDE INCINERATOR, LONG ISLAND NUMBER 3 FURNACE
(NOVEMBER 1968)

Component	Conc. ppm/v	Rate of discharge (ft^3/day, 554F)	Rate of discharge (ft^3/day, STP*)	Rate of discharge (g. moles/day)	lb/day	lb/ton refuse
Effluent	-	183×10^6	89×10^6	112×10^6	7×10^6	47×10^3
SO_2	33	6039	2937	3696	520	3.5
Total HC as CH_4	240	43,920	21,360	26,880	946	6.3
Total acids as HAc†	1	183	89	112	15	0.1
Total Aldehydes and ketones as HCHO	0.7	128	62	78	5	0.03
HCl‡	113	20,679	10,057	12,656	1016	6.8
HF‡	0	0	0	0	0	0
H_2SO_4‡,§	76	13,908	6,764	8,512	1835	12

*STP, 30 inches mercury and 32F or 760 mm mercury and 0C.

†Total acids include acetic, propionic and butyric expressed as acetic acid.

‡Chloride, fluoride, and sulfate are expressed as the respective acids.

‡,§Same contribution by sulfur dioxide although sulfite was not detected; sulfite is air oxidized to sulfate to same extent in alkaline solution.

TABLE 11

SOME STACK EMISSIONS FROM THE OCEANSIDE INCINERATOR, LONG ISLAND, NUMBER 3 FURNACE
(FEBRUARY 1969)
(N_2 = 78.9%, O_2 = 18.8%, CO_2 = 1.25%, CO <0.01%)

Component	Conc. ppm/v	Rate of discharge (ft^3/day, 545F)	Rate of discharge (ft^3/day, STP*)	Rate of discharge (g. moles/day)	lb/day	lb/ton refuse
Effluent	-	180×10^6	88×10^6	111×10^6	7×10^6	46.7×10^3
SO_2	27	4,900	2,400	3,000	430	2.9
Total HC as CH_4	150	27,000	13,200	16,600	590	3.94
Total acids as HAc†	1	180	88	111	14.4	0.10
Total Aldehydes and ketones as HCHO	0.26	47	23	29	0.19	0.001
HCl‡	96	17,300	8,500	11,700	940	6.3
HF‡	0.65	12	5.7	7.2	0.32	0.002
H_2SO_4‡,§	46	8,300	4,100	5,200	1,130	7.5

*STP, 30 inches mercury and 32F or 760 mm mercury and 0C.

†Total acids include acetic, propionic and butyric expressed as acetic acid.

‡Chloride, fluoride, and sulfate are expressed as the respective acids.

‡,§Same contribution by sulfur dioxide although sulfite was not detected; sulfite is air oxidized to sulfate to same extent in alkaline solution.

TABLE 12

SOME STACK EMISSIONS FROM THE FLUSHING INCINERATOR, NEW YORK CITY
(NOVEMBER 1968)

Component	Conc. ppm/v	Rate of discharge (ft^3/day, °F)	Rate of discharge (ft^3/day, STP*)	Rate of discharge (g. moles/day)	lb/day	lb/ton refuse
Effluent**	-	257×10^6 (698)	111×10^6	140×10^6	9×10^6	3×10^3
Total acids as HAc[3]	1	257	111	140	18.5	0.06
Total Aldehydes and ketones as HCHO	9.2	2364	1021	1288	85	0.28
HCl[4]	38	9766	4218	5320	427	1.4
HF[4]	0	0	0	0	0	0
H_2SO_4[4,5]	39	10,023	4329	5460	1177	3.9
Effluent***	-	158×10^6 (581)	74×10^6	93×10^6	6×10^6	3×10^3
SO_2	20	3160	1480	860	262	1.3
Total HC as CH_4	160	25,280	11,840	14,880	524	2.6

*STP, 30 inches mercury and 32F or 760 mm mercury and 0C.

**Three furnaces in operation.

***Two furnaces in operation.

[3]Total acids include acetic, propionic, and butyric expressed as acetic acid.

[4]Chloride, fluoride, and sulfate are expressed as the respective acids.

[4,5]Same contribution by sulfur dioxide although sulfite was not detected; sulfur is air oxidized to sulfate to same extent in alkaline solution.

TABLE 13

SOME STACK EMISSIONS FROM THE FLUSHING INCINERATOR, NEW YORK CITY
(FEBRUARY 1969)
(N_2 = 79.3%, O_2 = 19.4%, CO_2 = 1.32%, CO <0.01%)

Component	Conc. ppm/v	Rate of discharge (ft^3/day, 831F)	Rate of discharge (ft^3/day, STP*)	Rate of discharge (g. moles/day)	lb/day	lb/ton refuse
Effluent	-	272×10^6	104×10^6	131×10^6	8.4×10^6	2.8×10^6
SO_2	29	7,900	3,010	3,800	530	1.8
Total HC as CH_4	21	5,700	2,180	2,750	96	0.32
Total acids as HAc†	1	270	104	131	17	0.06
Total Aldehydes and ketones as HCHO	0.84	230	87	110	7.2	0.024
HCl‡	40	10,900	4,160	5,250	420	1.4
HF‡	0.85	230	88	111	4.8	0.16
H_2SO_4‡,§	25	6,800	2,600	3,280	700	2.34

*STP, 30 inches of mercury and 32F or 760 mm mercury and OC.

†Total acids include acetic, propionic and butyric expressed as acetic acid.

‡Chloride, fluoride, and sulfate are expressed as the respective acids.

‡,§Same contribution by sulfur dioxide although sulfite was not detected; sulfite is air oxidized to sulfate to same extent in alkaline solution.

TABLE 14

SOME STACK EMISSIONS FROM MUNICIPAL INCINERATORS IN THE NEW YORK CITY METROPOLITAN AREA
FALL 1968 AND WINTER 1968-69
(lb/ton refuse)

Emission	FALL				WINTER			
	73rd St.	Hamilton Ave.	Ocean-side	Flushing	73rd St.	Hamilton Ave.	Ocean-side	Flushing
SO_2	5*	2.1	3.5	1.3*	5.8	1.5	2.9	1.8
Total HC as CH_4	0.46+	0.09	6.3	2.6*	2.14	0.02	3.9	0.32
Total acids as HAc	0.11+	<0.08	0.1	0.06+	0.14	0.08	0.1	0.06
Total Aldehydes and ketones as HCHO	0.30*	0.024	0.03	0.28	0.16	0.09	0.001	0.024
HCl	2.7+	~~2.2~~	6.8	1.4+	6.4	5.0	6.3	1.4
HF+	0+	0	0	0+	0	0.03	0.002	0.16
H_2SO_4	7.3+	5.3	12	3.9+	11.0	7.5	7.5	2.3

*Two furnaces in operation.

+Three furnaces in operation.

+Detection limit of analytical method, 0.02 ppm/$\frac{1}{2}$ in gaseous effluent.

TABLE 15

ANALYSIS OF QUENCH WATER AND ORGANIC CONTENT OF ASHES FROM FOUR MUNICIPAL INCINERATORS IN THE NEW YORK CITY METROPOLITAN AREA
(FALL 1968, WINTER 1968-69)

	73rd St.	Hamilton Avenue	Oceanside	Flushing
ph	10-11, 9	9, 9	7, 6	7.1, 9
Total dissolved solids (mg/ml)	2.0, 4.1	0.90, 5.6	-, -	1.0, 1.8
		Anionic content (mg/ml)		
Cl^-	0.38, 0.55	0.09, 0.85	-, -	0.05, 0.34
$CO_3^= + PO_4^= + SiO_3^=$ as $CO_3^=$	0.10, 0.14	0.14, 0.15	0.16, 0.32	0.24, 0.07
$SO_4^=$	0.24, 0.27	0.08, 0.40	0.04, 1.48	0.04, 0.12
		Ashes		
% wt. ether soluble	1.9, 0.4	4.0, 1.4	1.9+, 0.7	0.9*, 1.6*

*Organic (gross) residue recognizable, e.g., hair, vegetable and fruit pieces, charred paper, etc. This is not included in the ether-soluble organic residue.

+Unwashed, fine, dry, ashes from cool furnace grating; charred pieces of paper visible.

two reasons. First, because a noticeable quantity of industrial refuse, including some synthetic textile, was normally incinerated at this plant together with the domestic and household material. Second, because of the three continuous units, the Hamilton Avenue plant was the only one without water sprays. Why inorganic gaseous emissions per unit weight of refuse should have been higher at the two plants outfitted with water sprays cannot be fully explained. It should be mentioned, however, that the residue from the Hamilton Avenue plant contained the largest amount of ether-soluble organic material (Table 15).

Airborne emission from the East 73rd Street incinerator stack was relatively richer in sulfur dioxide and sulfuric acid. The Oceanside incinerator gaseous stack effluent had the highest hydrocarbon content. Organic acids values were essentially the same in all cases. Hydrogen fluoride was found in the effluent from three of the four units only in the winter samples (Tables 5, 9, 11, 13 and 14).

Quench water from the Flushing plant had the lowest amount of dissolved solids. The grate ash from this plant was also richest in gross organic residue (Table 15). Anionic contents of quench water samples taken, during the fall and again in the winter, from each of the four incinerator plants were compared (Table 15). Carbonate values for all samples were essentially the same. Sulfate values were higher in the winter than in the fall.

Grate ashes from the Oceanside and the East 73rd Street incinerators contained essentially the same quantities of ether-soluble organics (Table 15).

Detailed Analysis of Gaseous Stack Effluent

As noted earlier, samples for the comprehensive analysis were taken at the Oceanside municipal incinerator plant in Hempstead, Long Island, and were representatively collected at a point beyond the fly-ash arrestors, downstream of the induced draft fan, whenever normally dry refuse was being incinerated in furnace No. A. The analytical results and rate of discharge data were compared (Table 16).

The components of the gaseous effluent resulting from the incineration of municipal refuse are many, and representative of numerous classes of both organic and inorganic substances. Thus one or more compounds representative of aliphatic, saturated and unsaturated, and aromatic hydrocarbons, organic acids, alcohols, keto alcohols, ketones, aldehydes, phenols, halogen, and other inorganic acids and inorganic acid anhydrides were identified (Table 16). Also evidenced were the very toxic hydrogen cyanide and selenium.

Miscellaneous Studies

In evaluating periodical variations in the concentration of any one major component of incinerator stack effluent, it is quite important to be cognizant of variations over periods shorter than the ones in question. Thus, concentration variations due to seasonal changes will become meaningful only after having a knowledge of variations within a season while a record of monthly variations becomes meaningful only after having knowledge of variations which occur from week to week or day to day. Clearly, continuous monitoring of the species is the ultimate answer.

TABLE 16

SOME GASEOUS EMISSIONS FROM THE OCEANSIDE INCINERATOR, HEMPSTEAD, LONG ISLAND
[N_2 = 79.9%, O_2 = 13.55%, 13.4%, 12.8%, 11.6%; CO_2 = 6.15%, 6.23%, 5.73%, 7.4%;
CO = 0.037%, 0.027%, 0.046%, 0.090%; H_2O = 8.4 o/v(5.3 o/w), 8.2 o/v(5.3 o/w)]

Component	Conc. (ppm/wt.)	Conc. (ppm/v)	Rate of discharge (ft^3/day, 600F)	Rate of discharge (ft^3/day, STP*)	Rate of discharge (g. moles/day)	lb/day	Refuse (lb/ton)	Comments
Effluent†	-	-	115×10^6	53×10^6	67×10^6	4.2×10^6	14×10^3	No. 2 Furnace
Methane	3.0	5.6	644	297	375	13	.04	
Ethane and acetylene				Traces				
High boiling hydrocarbon	0.04	0.007	0.81	0.37	0.47	0.17	0.0006	Class ident. by I.R., M.W.~200
Benzene	0.005	0.002	0.23	0.11	0.13	0.021	0.00007	
Formic Acid	114	70	8,050	3,700	4,700	480	1.6	
Acetic acid	1.2	0.6	69	32	40	5.0	0.017	
Methanol	0.05	0.04	4.6	2.1	2.6	0.21	0.0007	
Ethanol	0.01	0.06	6.9	3.2	4.0	0.42	0.0014	
n-Butyl alcohol	0.01	0.004	0.46	0.21	0.26	0.04	0.0001	
n-Amyl alcohol	0.01	0.004	0.46	0.21	0.26	0.04	0.0001	

TABLE 16 (Cont'd.)

SOME GASEOUS EMISSIONS FROM THE OCEANSIDE INCINERATOR, HEMPSTEAD, LONG ISLAND
[N_2 = 79.9%, O_2 = 13.55%, 13.4%, 12.8%, 11.6%; CO_2 = 16.15%, 6.23%, 5.73%, 7.4%; CO = 0.037%, 0.027%, 0.046%, 0.090%; H_2O = 8.4 o/v(5.3 o/w), 8.2 o/v(5.3 o/w)]

Component	Conc. (ppm/wt.)	Conc. (ppm/v)	Rate of discharge (ft^3/day, 600F)	Rate of discharge (ft^3/day, STP*)	Rate of discharge (g. moles/day)	lb/day	Refuse (lb/ton)	Comments
High M.W. alcohol	0.04	0.007	0.81	0.37	0.47	0.17	.0006	Class ident. by I.R., M.W.~200
Keto alcohol	0.04	0.007	0.81	0.37	0.47	0.17	.0006	Class ident. by I.R., M.W.~200
Acetone	12.4	6.1	700	320	420	52	0.17	
Methyethyl ketone	0.05	0.02	2.3	1.2	1.5	0.21	0.0007	
Acetaldehyde	0.07	0.04	4.6	2.1	2.6	0.30	0.001	
Phenol	0.2	0.06	6.9	3.2	4.0	0.84	0.003	
Alkyl halides	NONE DETECTED		-	-	-	-	-	limit of sensitivity <0.07 ppm
Hydrogen cyanide	0.04	0.04	4.6	2.1	2.6	0.17	0.0006	found in only one sample
Hydrofluoric acid*	1.0	1.4	160	74	93	4.2	0.014	
Hydrochloric acid*	131	102	11,700	5,400	6,800	550	1.83	
Selenium	0.05	0.02	2.3	1.2	1.5	0.21	0.0007	Se or as H_2Se by volume

TABLE 16 (Cont'd.)

SOME GASEOUS EMISSIONS FROM THE OCEANSIDE INCINERATOR, HEMPSTEAD, LONG ISLAND
[N_2 = 79.9%, O_2 = 13.55%, 13.4%, 12.8%, 11.6%; CO_2 = 16.15%, 6.23%, 5.73%, 7.4%;
CO = 0.037%, 0.027%, 0.046%, 0.090%; H_2O = 8.4 o/v(5.3 o/w), 8.2 o/v(5.3 o/w)]

Component	Conc. (ppm/wt.)	Conc. (ppm/v)	Rate of discharge (ft^3/day, 600F)	Rate of discharge (ft^3/day, STP*)	Rate of discharge (g. moles/day)	lb/day	Refuse (lb/ton)	Comments
Effluent§	-	-	183×10^6	89×10^6	112×10^6	7×10^6	47×10^3	No. 3 Furnace
H_2SO_4†,§§	-	76	13,908	6,764	8,512	1,835	12	
SO_2	-	33	6,039	2,937	3,696	520	3.5	

*STP, 30 inches mercury and 32F or 760 mm mercury and OC.

†Stack effluent from No. 2 furnace.

†Sulfate expressed as the acid.

§Stack effluent from No. 3 furnace.

†,§§Same contribution by sulfur dioxide although sulfite was not detected; sulfite is air oxidized to sulfate to same extent in alkaline solution.

For example, on May 23, 1968, the concentration of total hydrocarbons as methane in the effluent from the stack of the East 73rd Street incinerator was recorded as 410 ppm by volume (Table 2). An additional six samples of the effluent were subsequently similarly taken on different days and each analyzed for total hydrocarbons as methane. The results were as follows:

Date	CH_4 (ppm/v)
June 18	350
June 19	4.6
June 20	3.2
June 26	8.5
June 27	4.7
June 28	4.2

Thus, two high, one in May and one in June, and five normal values were recorded over a relatively short period. Wet refuse may have been responsible for the first peak concentration (May 23). The reason for the second peak concentration (June 18) was not known. It is nevertheless important to note that such situations can arise. Clearly, the magnitude of these variations must be taken into account in evaluating concentration changes at long time-intervals.

It has been suggested that the combustion product of cigarette paper may prove hazardous to the smoker's health because of its selenium content. Since many tons of various kinds of paper and paper products are daily incinerated in a metropolitan area such as New York City, it became of

particular interest to record selenium concentrations in municipal incinerator stack emission. The Oceanside municipal incinerator plant was chosen for this study.

Samples of incinerator stack effluent condensable at 0°C (see section on "Sampling Apparatus" and "Detailed Analysis of Stack Effluent") and samples of stack effluent collected in a Greenburg-Smith impinger containing 1N NaOH and fly ash were quantitated spectrophotometrically for selenium.*

The concentration of selenium in the three sample fractions collected were compared (Table 17). Essentially all of this element and its compounds seemed to be concentrated in fly ash collected from the (cyclone) fly ash arrestors.

Table 17

CONCENTRATION OF SELENIUM IN STACK EFFLUENT AT THE OCEANSIDE MUNICIPAL INCINERATOR, HEMPSTEAD, LONG ISLAND

Fraction	ppm/wt
0°C Trap condensate	0.05
Aq. NaOH solubles (impinger)	0.01**
Fly ash	0.7

*The sample is oxidized with conc. nitric acid. SeIV reacts with 2,3-diaminonaphthalene to form a red-colored and strongly fluorescent complex. The fluorescence intensity is measured at an exciting wave length of 390 mμ and a fluorescent wave length of 590 mμ. A linear calibration curve is obtained over the range 0 to 1 μg Se for 10 ml toluene (used to extract the complex). The absorbance of the solution sample is determined at 390 mμ. The calibration curves follow Beer's law over the range 0 to 20 μg Se per 5 ml toluene in a 1-cm cell at this wavelength. Publication pending, Manual of Methods for Ambient Air Sampling and Analysis, Intersociety Committee, to be published by American Public Health Association, 1015-18th Street, N.W., Washington, D.C.

**The sensitivity of the analytical procedure used to quantitate selenium is less than 0.01 μg.

General Comments

The tabulated data clearly speaks for itself. Thus it becomes immediately apparent that municipal incinerator gaseous effluent is significantly richer in inorganics such as hydrogen chloride, sulfuric acid, and sulfur dioxide than in organics such as hydrocarbons, aldehydes, alcohols, ketones, esters, and organic acids. The presence of such relatively high concentrations of stable inorganic products and generally low concentrations of relatively unstable (at incinerator operating conditions) organic products indicates a high combustion efficiency. Hydrogen chloride is mainly a product of the incineration of chlorinated plastic material such as polyvinyl chloride, while the incineration of sulfur-containing synthetic and natural rubber products undoubtedly contributes to the overall emission of sulfur oxides and sulfuric acid. Teflon-like products and some insecticides would be a source of hydrogen fluoride.

In order to control air pollution and to eliminate, insofar as possible, corrosion of metallic incinerator parts, better control of these emissions is indicated.

Also clear and quite important is the fact that the total hydrocarbon concentration in the effluent varied significantly over relatively short periods of time. Thus, if the concentrations of other gaseous species change with equal frequency, the tabulated results must be evaluated with this fact in mind. Continuous variations in the solid content of the quench water and in the organic content of the residual ash might also

be expected. With respect to the latter, the question of a truly representative sample also arises.

RECOMMENDATIONS FOR FUTURE WORK

A survey of the literature and a review of the data on airborne emissions from municipal incinerators clearly indicated a limited knowledge in this area and a real need for additional, basic information. This need was only in part satisfied as a result of the field and laboratory experimental work described and evaluated in this report. And, thus, although the above recorded, experimental data are extremely informative and significant, they clearly indicate a need for supplementary and new, additional studies.

Municipal incinerator stack effluent is richer in inorganic than in organic components. Most of the inorganics are toxic and corrosive. Means should be sought to decrease such undesirable emissions by modification of operational conditions and procedures to include the addition of a carbonate for example, to the refuse charge, or by use of practical control equipment. Further study in this area is also indicated.

The concentration of hydrocarbons and probably of other species in incinerator gaseous emission varies significantly over short time intervals. A knowledge of such variations, during normal operation of the incinerator unit, is necessary in order to correctly extrapolate and evaluate measurements taken at infrequent intervals.

Incineration efficiency cannot be evaluated on the basis of the magnitude of gaseous emission values alone. A thorough consideration of the

furnace residue appears also to be necessary in order to arrive at a meaningful conclusion. Study of this aspect should be expanded. Elemental material balances should prove quite valuable.

Water spray chambers designed to cool the very hot furnace combustion products prior to discharge do not seem effective in removing water-soluble gaseous products. This question might be resolved by a quantitative analysis of the gaseous incineration products (on a dry basis) before entering the water spray chamber and after leaving it, in conjunction with an analysis of the discharged spray water.

Gaseous emissions from rotary kiln incinerators have not been adequately evaluated. Such units are still being used to incinerate municipal refuse in some major cities in the United States, for example the Coconut Grove incinerator in Miami and the Southwest incinerator in Chicago. Comprehensive discharge data from such units would be extremely informative and valuable.

The town of North Hempstead, Long Island, incinerates municipal refuse in rocking grate furnace units with unusually long secondary combustion chambers. Gaseous stack emission from such units might be expected to be lower in organic content. Substantiation of this will prove quite valuable especially in planning construction of future incinerator plants.

Emission resulting from the incineration of other than municipal and household, domestic refuse have not been adequately labelled. Most hospital complexes in the New York City and other large metropolitan areas are equipped with "pathologic" incinerators. These units are used to incinerate refuse that the city is not permitted by law to collect, such as

dead animals and animal waste, infectious bandages, pads and wrappings, disposable containers, bacterial cultures and bacteriologic, pathologic, biological, and surgery wastes. Such waste is usually rich in plastics.

These incinerators range in size. The Montefiore unit in the Bronx, New York City, can handle 750 lbs per day. Some are built to incinerate as much as 3,000 lbs per day.

There are 20 municipal and over 100 private hospitals in the city of New York. Each incinerate different quantities of these unique solid wastes. The total amount incinerated daily is significant. Emissions and rates of discharge from such incinerator units should be recorded.

Most municipal incinerators usually shut down late on Saturday and resume operations early on the following Monday. During the shutdown and the startup operations, the furnace units do not operate at design capacity, and incineration efficiencies may be low. Thus stack emissions during these periods are probably relatively rich in organics. The overall total hydrocarbons, organic acids, aldehydes, esters, etc., emitted during one or two hours may possibly be as much as the total six-day emission of these substances when the incinerator is operating normally. It thus becomes important to establish the composition of the stack effluent and to determine the rate of discharge of various major components during the few hours preceding and up to shutdown and during the few hours following startup until the incinerator operates normally.

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